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METEOROLOGICAL RESEARCH COMMITTEE

Average height of the standard isobaric surfaces over the area from the North Pole to 55°N. in January

by
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1. Introduction

Geophysical Memoir 85 - Upper Winds over the World - published in 1950, includes seasonal charts of the average heights of the isobaric surfaces 700, 500, 300, 200 and 130 mb. These charts were necessarily based on data for earlier years when the network of upper air stations was, in most parts of the world, extremely sparse. All available data were used irrespective of period, but the approach had still to be largely statistical. It was realised at the time of publication that these charts would need revision and, by about 1953, the increasing number of upper air data available made such a revision feasible.

The charts in G.M.85 are on a Mercator projection and do not extend beyond 75°N. In view, therefore, of the increasing importance of the polar regions for aviation, it was decided to start the revision by constructing circumpolar charts for the standard isobaric surfaces. The charts of the original memoir apply to the four seasons, each of three months. However, changes within a season can be very marked and to obviate the difficulty of maintaining equal weighting all over the chart for each month of the season, the charts were to be drawn for the mid-season months - January, April, July and October. Further, attention was to be confined to a fixed period rather than to one varied to include earlier years in particular areas. The five-year period 1949-53 was chosen mainly because January, 1949 marked the beginning of both regular CLIMAT TEMP data and publication by the meteorological service in western Germany (1) of monthly mean 500 mb. contour charts for a large part of the northern hemisphere. Finally it was decided to extend the range to 100 mb. and to include a chart for 150 mb.

This paper presents the circumpolar average contour charts for January and a discussion of the method used in their preparation.

2. The data

The sources of the data used in the preparation of the charts are given in the following list:-

(a) Climat temp reports.

Up to 200 mb. these give a reasonable network of data except over Russia and eastern Europe.

(b) Data tabulations from U.S.W.B. Daily Series Synoptic Weather Maps.

These publications give daily upper air reports from stations in the northern hemisphere. Daily values have been extracted to give monthly mean heights for:-

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(i) Climat stations at 200 and 100 mb.

(ii) Non-climat stations at all levels - in particular, Russia, Greenland and the Aleutians.

(iii) Certain climat stations at all levels, where the climat value seemed dubious.

(c) Micro-film.

Certain data for limited periods have been obtained from micro-film:-

(i) For Sola, Gardermoen, Tromso, Keflavik, Jan Mayen and weather ship "M" - from Norway.

(ii) For Stockholm - from Sweden.

(iii) For American weather ships "A", "B" and "C".

(d) Aerologiske Observationer i Danmark.

Data for limited periods for Thorshavn and Copenhagen.

(e) Hollerith tabulations in the Upper Air Climatology Branch.

Data for British stations and weather ships "I" and "J" were obtained from Hollerith tabulations.

(f) Manuscript data from U.S.A.

Data for Alaska at 200, 150 and 100 mb. were obtained from U.S.W.B.

The U.S.W.B Daily Series Synoptic Weather Maps for January, 1953 have not been received, so for this month additional sources of data were used.

(g) Dunstable synoptic charts.

Daily values were read off:-

(i) For eastern Europe, Russia in Europe and Greenland - all levels.

(ii) For climat stations in Europe - 200 and 100 mb. levels only.

(h) Teleprinter data from Dunstable.

All Russian data received at Dunstable were examined and data for stations in Russia in Asia were extracted.

(i) Russian data already extracted by Dunstable for use in drawing the climat charts were incorporated with (h) above.

(j) Manuscript data from Canada.

Data for Canadian stations at 200, 150 and 100 mb. were obtained from the Canadian Meteorological Service.

(k) German Daily Weather Report.

The daily weather report published by the meteorological service in western Germany (1) contains a 500 mb. contour chart covering a large part of the northern hemisphere. Daily values of 500 mb. height at a few stations in Siberia were extracted.

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3. Method of constructing the charts

(1) General. It was found necessary to draw a separate set of charts for each year since:-

(a) The Russian data were very sparse; some of the monthly means were based on few observations and very few stations were available with equal reliability for all five years. Hence the only way to make use of all available data was to consider each year separately.

(b) Some of the climat data were obviously incorrect (possibly due to errors in transmission) and could most easily be checked on a yearly basis.

(c) At the upper levels, data were biased owing to loss of observations and, moreover, the number of data (particularly at 100 mb.) increased steadily through the period 1949 - 53.

Further, in drawing the individual charts, the area was divided into two sectors for which somewhat different procedures had to be adopted. For the first sector from 180°W. to 20°E., comprising the eastern Pacific, North America, the North Atlantic and western Europe, the data were reasonably adequate for the straightforward drawing of the charts. For the remaining sector from 20°E. to 180°E., comprising European and Asiatic Russia and the western Pacific, data were sparse and special procedures, described below, had to be adopted. These two sectors are referred to in the paper as the western and eastern sectors respectively.

(2) 700 mb., 500 mb. and 300 mb. charts. When all available data were plotted, it proved possible to draw the mean contours with some degree of confidence except over Russia in Asia. To assist in drawing this area of the chart, use was made of the monthly mean 500 mb. contour charts published in the monthly supplement to the German Daily Weather Report. These particular charts were used since reference to the corresponding daily charts suggested that more data from Russia in Asia were available in Germany than at Dunstable. Values of 500 mb. height were read off these charts for each of the five Januaries at a set of grid points covering the eastern sector and plotted on the working charts of 500 mb. contours. With the aid of these grid values and the Russian data available the drawing of the five 500 mb. contour charts was completed.

Unfortunately similar assistance at 700 mb. over Russia was not obtainable, so charts of 700-500 mb. thickness were next plotted for the available data for each January. It proved possible to draw these charts completely, though the isopleths over Russia were tentative. Values of 500 mb. height and of 700-500 mb. thickness were then read off at a set of grid points covering the eastern sector. By subtraction five sets of grid values of 700 mb. height were obtained and plotted on the working charts. The drawing of the five 700 mb. contour charts was then completed. Finally, for each year, the two contour charts and the thickness chart were examined together and minor adjustments made over Russia to produce the most plausible mutually consistent patterns.

The 300 mb. contour charts were then constructed in a similar manner, i.e. charts of 500-300 mb. thickness were drawn first and, over the eastern sector, grid values added to the 500 mb.. height grid values to obtain five sets of 300 mb. height grid values. Again, for each year, the three contour charts and two thickness charts were examined together and minor adjustments made where necessary.

The average contour charts of the 700 mb., 500 mb. and 300 mb. surfaces for the period 1949-53 were then constructed by reading off values for the individual years at a set of grid points and meaning.

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(3) 200 mb. charts: effect of the tropopause. A new problem arose at the 200 mb. level, since no useful data were available over Russia. It was decided, therefore, to construct, for the eastern sector, a chart of average 300-200 mb. thickness, by making use of temperature lapse rates derived from the charts of average temperature of standard isobaric surfaces already drawn in the Upper Air Climatology Branch. A further complication arose because the average pressure at the tropopause was between 300 and 200 mb. almost everywhere over the area covered by the chart. However, by making use of the charts of average pressure and temperature at the tropopause, already constructed, a "correction for tropopause", to be applied to the thickness obtained from the mean temperature of the layer (assumed to be the mean of the temperatures at 200 and 300 mb.), was evaluated in the following manner. For any point on the chart let

T_T, p_T be the average temperature and pressure at the tropopause,

T_1, T_2 the average temperature at two standard isobaric surfaces

p_1 and p_2, where $p_1 > p_T > p_2$,

$\Delta\phi$ the difference in geopotential between the two isobaric surfaces.

Then $\Delta\phi = R\, T'_m \log_e \frac{p_1}{p_2}$ in c.g.s. units

where R is the gas constant for dry air and T'_m is the mean virtual temperature (in degrees absolute) of the layer.

Writing $T'_m \simeq \frac{T_1 + T_2}{2}$, that is, ignoring the presence of the tropopause, a first approximation $\Delta\phi'$ to $\Delta\phi$ may be at once evaluated from standard tables, e.g. Smithsonian Meteorological Tables.

Taking into account the tropopause, a better approximation to $\Delta\phi$ is given by the expression

$$R\,\frac{T_1+\overline{T_T}}{2}\log_e p_1/p_T + R\,\frac{T_T+\overline{T_2}}{2}\log_e p_T/p_2$$

and a "correction for tropopause", C, was defined as

$$C = -\Delta\phi' + \left(R\,\frac{T_1+\overline{T_T}}{2}\log_e p_1/p_T + R\,\frac{T_T+\overline{T_2}}{2}\log_e p_T/p_2\right).$$

This may be rewritten

$$C = -R\left[\tfrac{1}{2}(T_1-\overline{T_2})\log_e p_T/p_2 + \tfrac{1}{2}(T_2-\overline{T_T})\log_e p_1/p_2\right].$$

With p_1 = 300 mb. and p_2 = 200 mb.,

$$-C \simeq 33.72(T_1-\overline{T_2})\log_{10} p_T/200 + 6(T_2-\overline{T_T}) \quad \text{in geopotential metres.}$$

The thickness of the layer was then evaluated as $\Delta\phi' + C$.

Charts of 300-200 mb. thickness were first drawn for the five years separately over the area where data were available, i.e. the western sector, and an average chart constructed by reading off grid values and meaning. Charts of 300 mb. temperature were then drawn over the

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whole area of the chart for the five years separately and a chart of average 300 mb. temperature constructed. From this chart, the temperature lapse rates mentioned above and the "correction for tropopause", values of average 300-200 mb. thickness were calculated at a set of grid points covering the eastern sector. These were then plotted on the working chart of average 300-200 mb. thickness. Unfortunately the pattern produced was most irregular and unconvincing.

It was then decided to investigate the average 200 mb. temperature chart. Over the western sector the average chart was constructed from the five charts for the individual years (the climat charts were accepted for 1951, 52 and 53, but charts had to be drawn for 1949 and 50) and the remaining sector completed by use of grid values derived from average 300 mb. temperatures and temperature lapses from 300 to 200 mb. Over the eastern sector the grid values of 200 mb. temperature and 300-200 mb. thickness were then adjusted by a somewhat laborious method of trial and error to obtain the most satisfactory mutually consistent patterns. The resulting average 300-200 mb. thickness chart was then added to the average 300 mb. contour chart to obtain the average 200 mb. contour chart.

(4) 150 mb. charts. A further problem arose at the 150 mb. level. While there were, of course, no data over the eastern sector, even over the western sector, where, at lower levels, the network of data had been adequate, the number of data varied through the period from poor in 1949 to good in 1953. The quality of the data was also more suspect owing to loss of observations with height.

To make the best use of the data available, it was decided to construct charts of 200-150 mb. thickness for the individual years over the western sector. In the first place, all data were ignored and thickness charts for the individual years were computed from the appropriate charts of 200 mb. temperature and the average temperature lapse from 200 to 150 mb. obtained from the charts of average temperature prepared in the Upper Air Climatology Branch. The mean temperature of the layer was assumed to be the 200 mb. temperature less half the temperature lapse from 200 to 150 mb. These computed charts were used in conjunction with the available data to construct the working charts of thickness for the individual years. By reading off grid values and meaning, a chart of average 200-150 mb. thickness was obtained over the western sector. The remaining sector was then completed by computing grid values of average thickness from values of average 200 mb. temperature and temperature lapse from 200 to 150 mb. Minor amendments were made in adjusting the two halves of the chart and in smoothing the pattern. A revised set of grid values was then read off over the whole chart and added to the 200 mb. height grid values to obtain the average 150 mb. contour chart.

(5) 100 mb. charts. The data at this level presented problems similar to those occurring at 150 mb. and a similar technique was employed. The grid values of average 200-150 mb. thickness were converted into grid values of average temperature of the layer and by combining these with grid values of average 200 mb. temperature, a chart of average 150 mb. temperature was produced. Over the western sector, grid values of 150 mb. temperature for the individual years were computed by a similar process applied to the corresponding yearly charts. It was now possible to construct a chart of average 150-100 mb. thickness in a manner exactly analogous to that described above for the 200-150 mb. thickness. Finally this last chart was added to the average 150 mb. contour

chart to obtain the average 100 mb. contour chart.

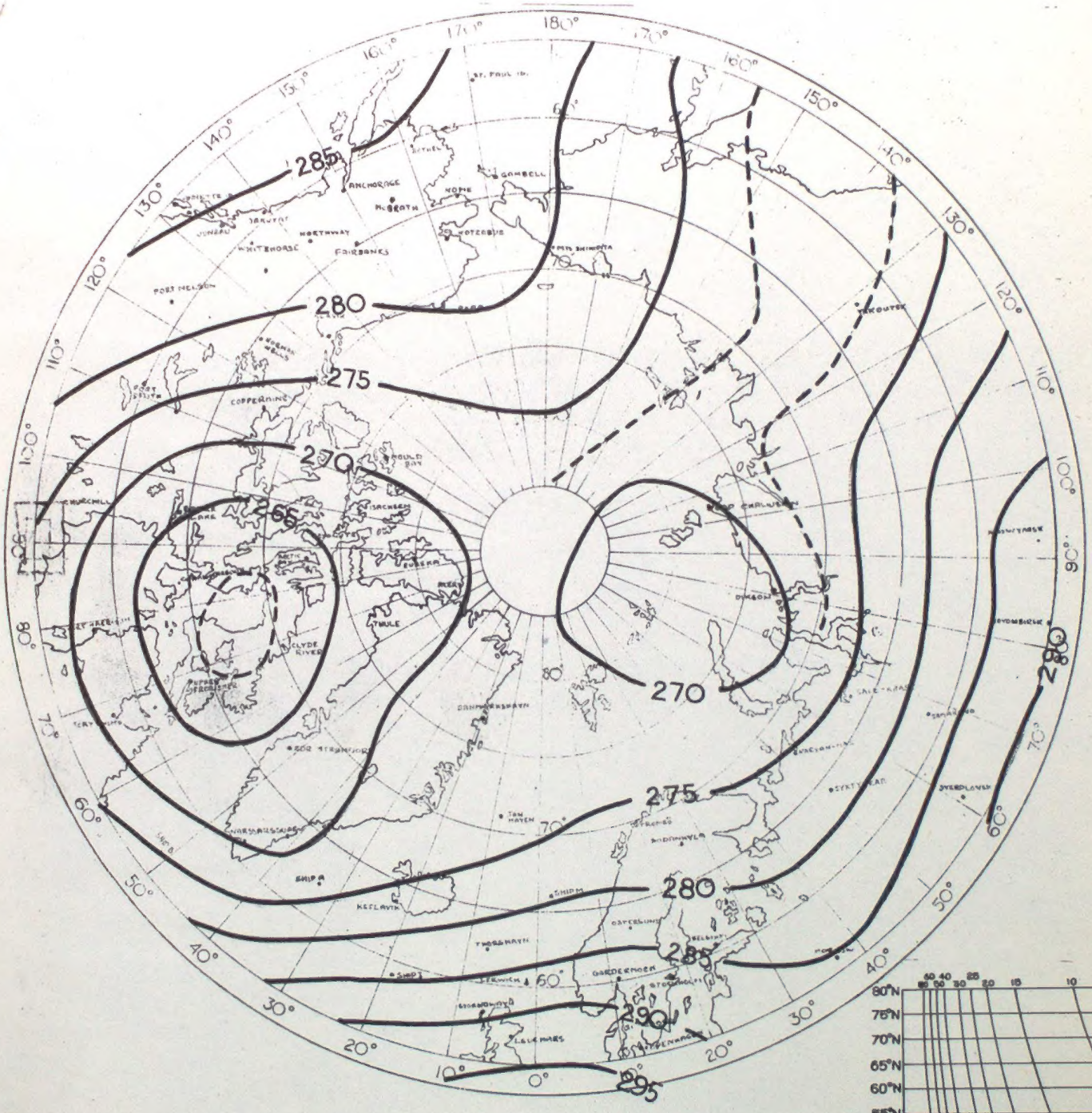
(6) Final adjustments to charts. The average charts of contours, temperatures, thicknesses and temperature lapses were now examined as a whole and certain anomalies over northern Russia were apparent. Data of any sort from this area were very sparse and of doubtful interpretation, so it was felt that some adjustment over this area was allowable. By redrawing the chart of average tropopause pressure and altering the temperature lapses above 300 mb. in the light of those over Canada, it was found possible to remove, at the same time, the major anomalies in contour height and temperature lapse. The charts were then redrawn over Russia from the 200 mb. level upwards.

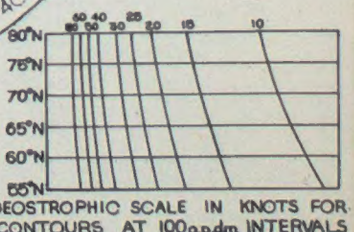
References

(1) Die Grosswetterlagen Mitteleuropas. Deutsche Wetterdienst. Bad Kissingen, Germany.

M.R.P. 918

Average 700mb. Contour heights (gp.d.m.)
JANUARY 1949-53





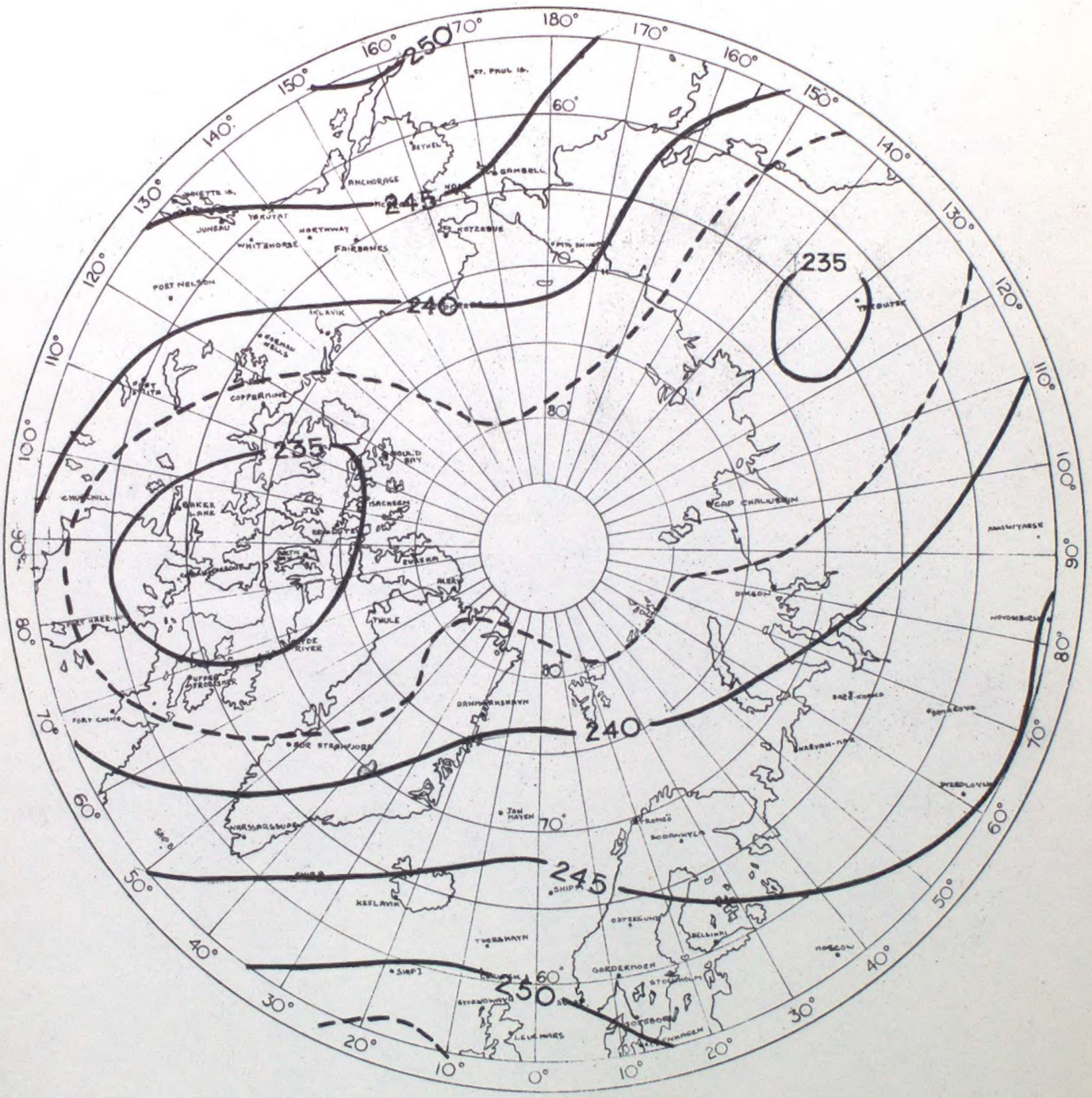
GEOSTROPHIC SCALE IN KNOTS FOR CONTOURS AT 100gp.dm. INTERVALS

Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

Average 700-500 mb. Thickness gp.dm.
JANUARY 1949-53

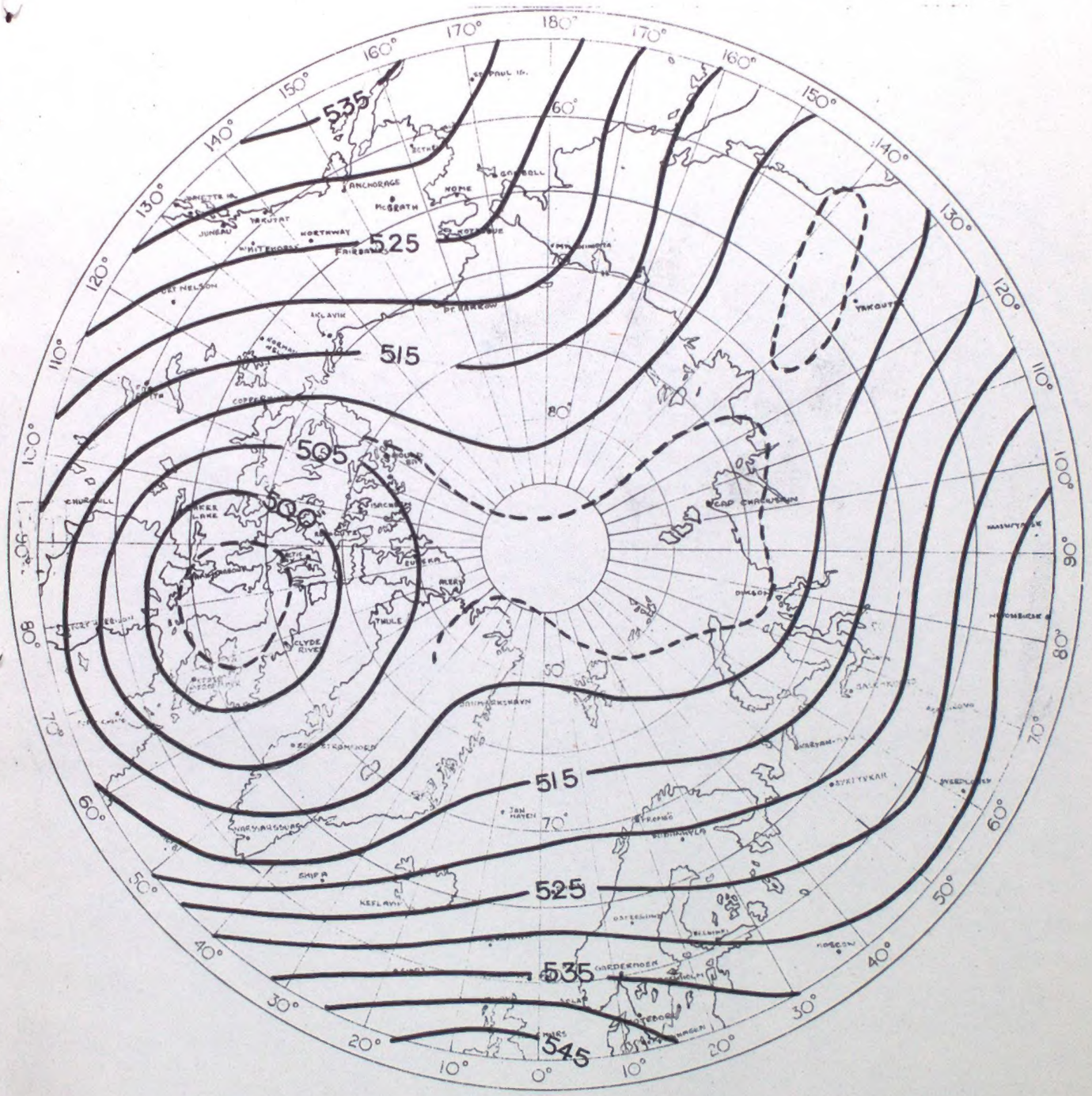


Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

Average 500mb. Contour heights (g.p.d.m.)
JANUARY 1949-53

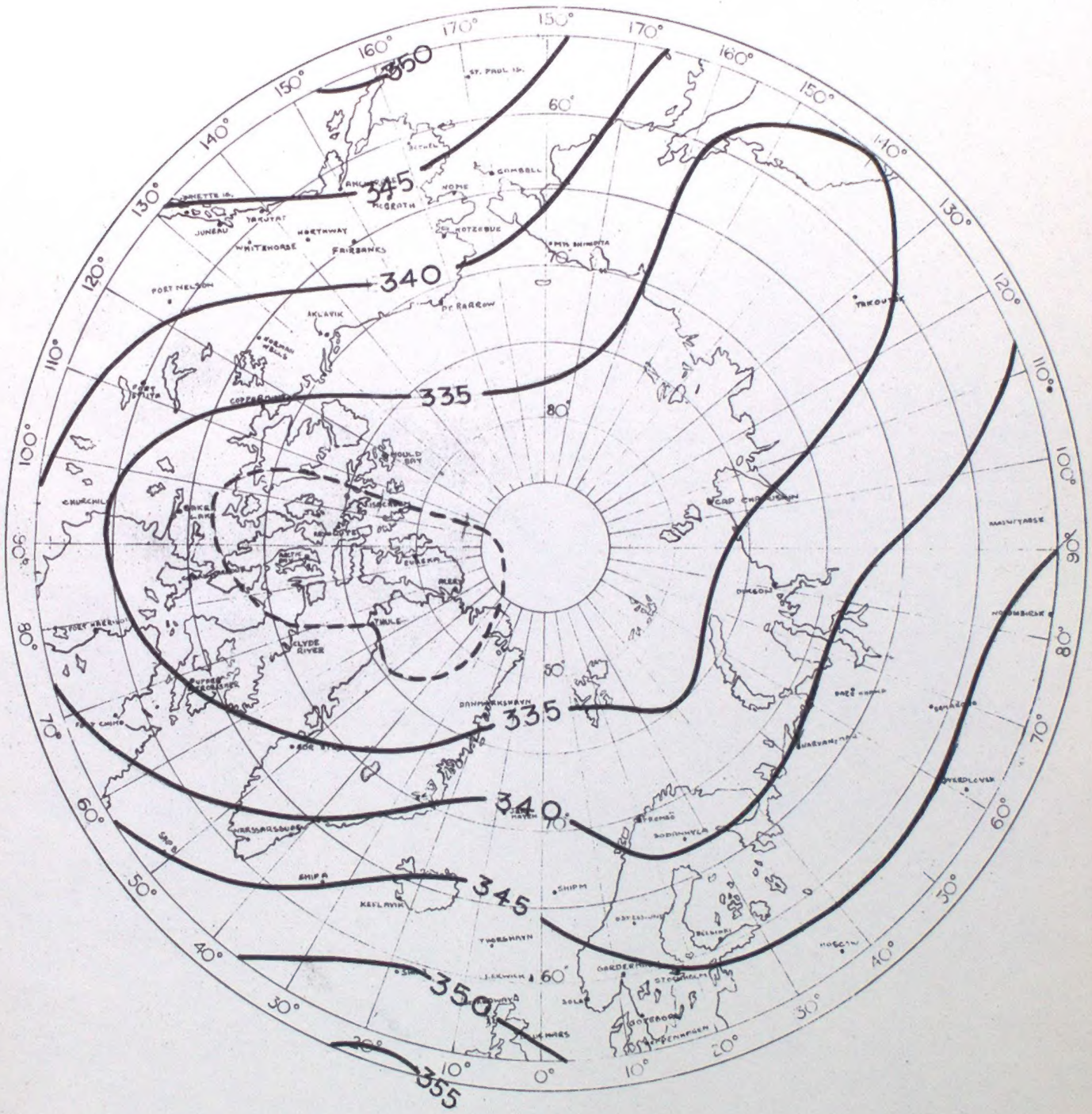


Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

Average 500-300mb. Thickness (gpdm)
JANUARY 1949-53



Height in dekametres

Upper Air Branch (M.O.23)

Average 300mb. Contour heights (g.p.d.m.)
JANUARY 1949-53

Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

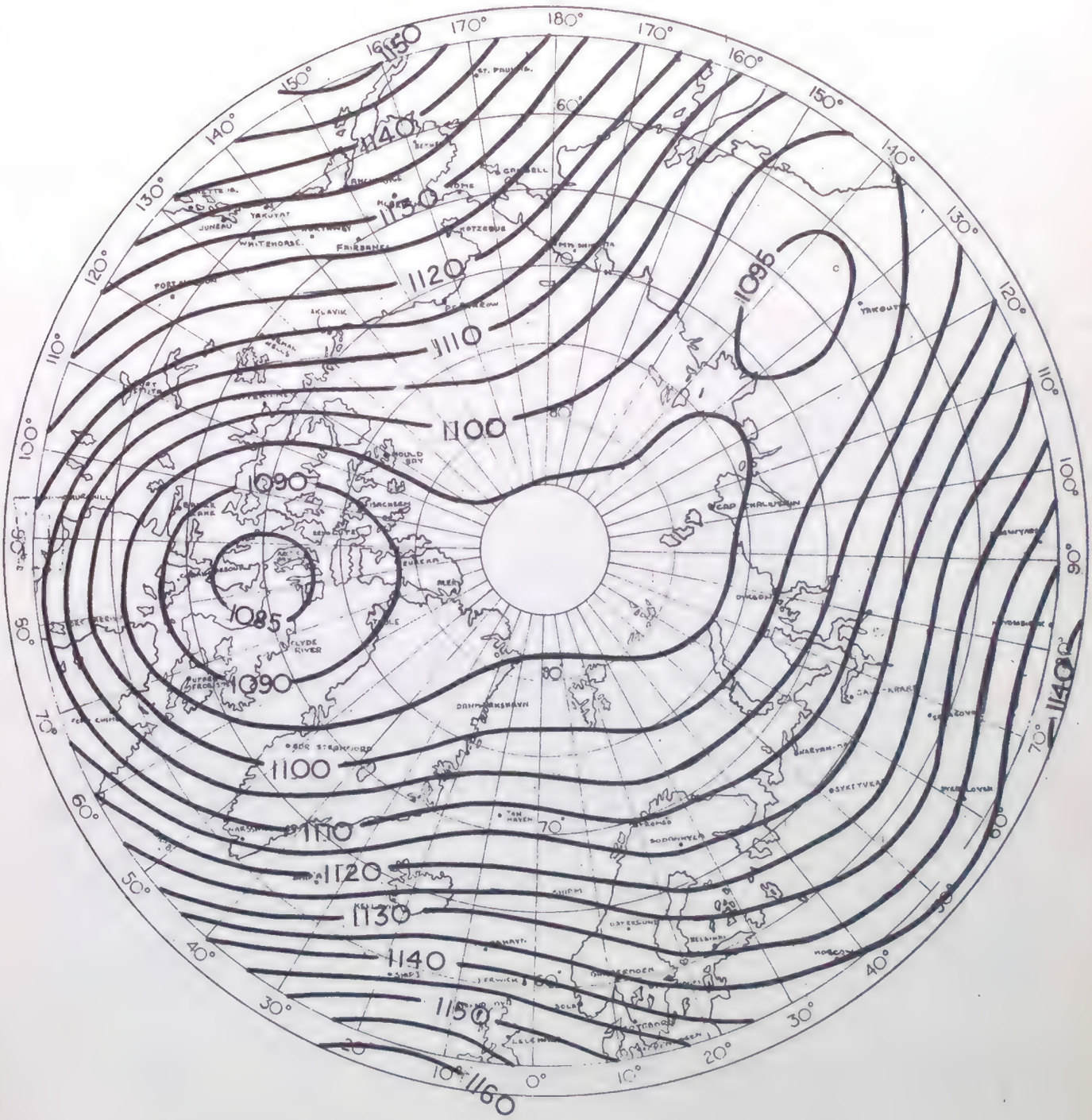
Average 300-200 mb. Thickness (gp.dm.)
JANUARY 1949-53

Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

Average 200mb. Contour heights (g.p.d.m.)
JANUARY 1949-53

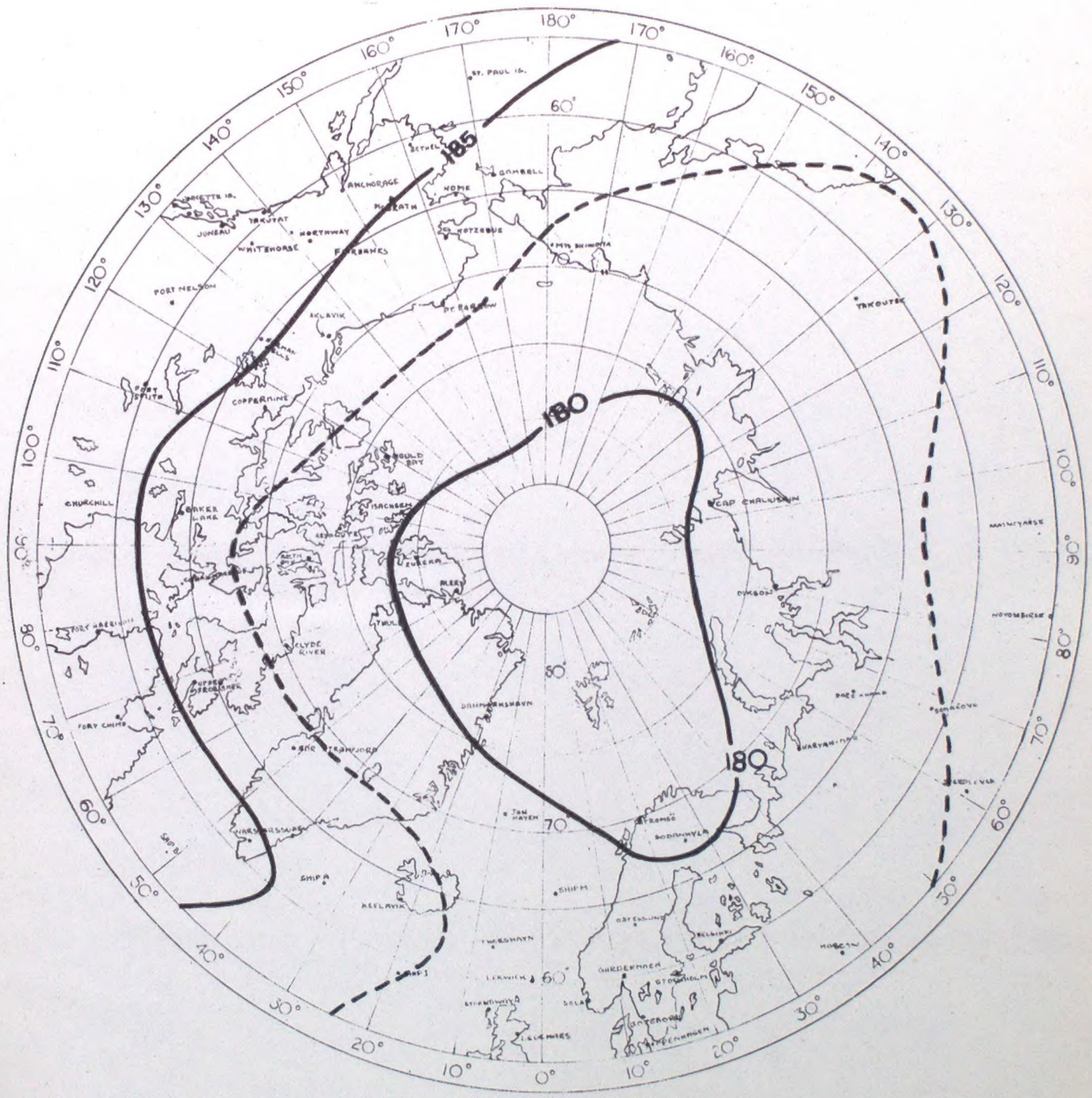


Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

Average 200-150 mb. Thickness (g.p.dm.)
JANUARY 1949-53

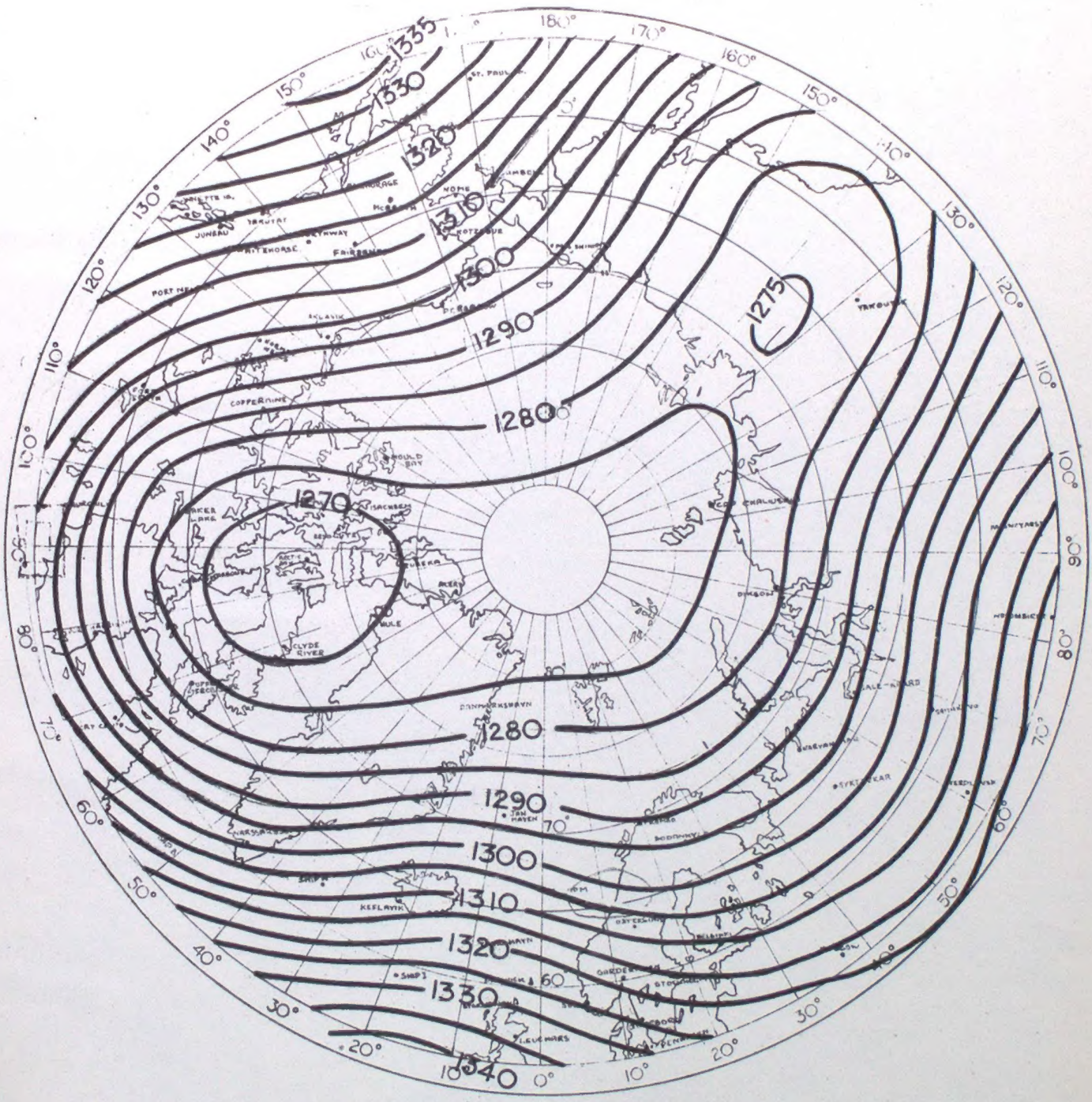


Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

Average 150mb. Contour heights (g.p.d.m.)
JANUARY 1949-53

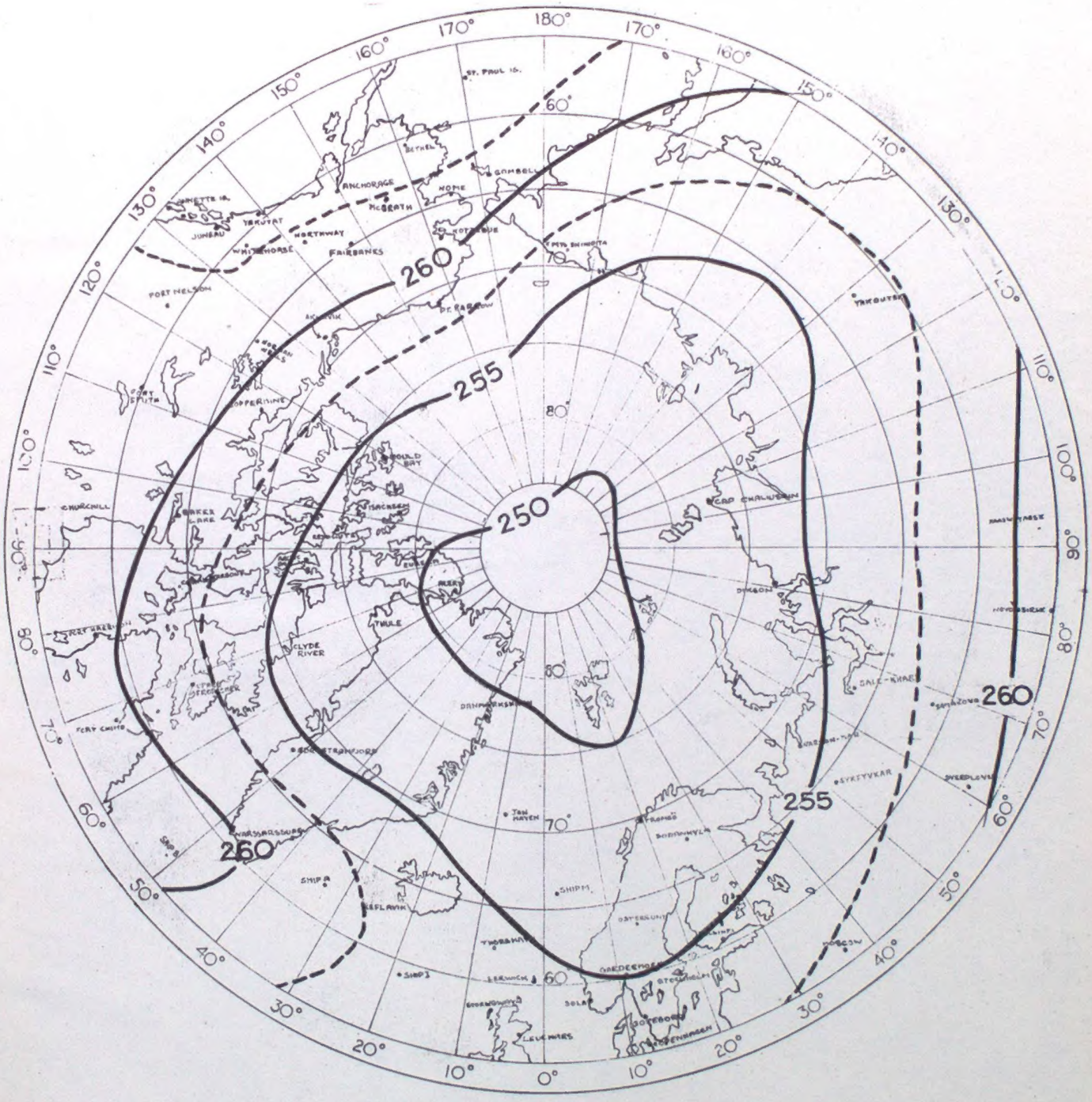


Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

Average 150-100 mb. Thickness (g.p.d.m.)
JANUARY 1949-53

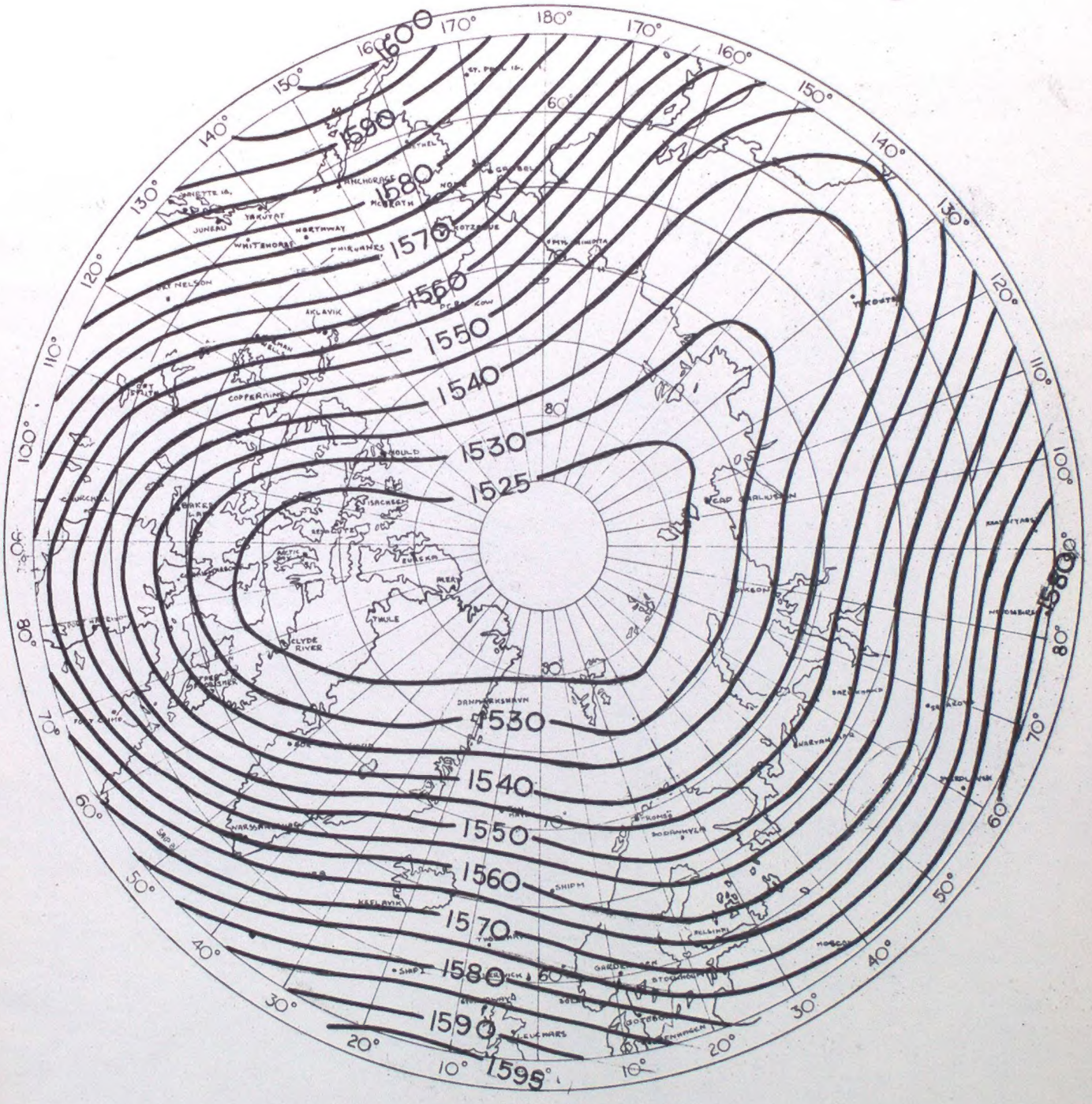


Height in dekametres

Upper Air Branch (M.O.23)

M.R.P. 918

Average 100 mb Contour heights (gp.dm)
JANUARY 1949-53



Height in dekametres

Upper Air Branch (M.O.23)